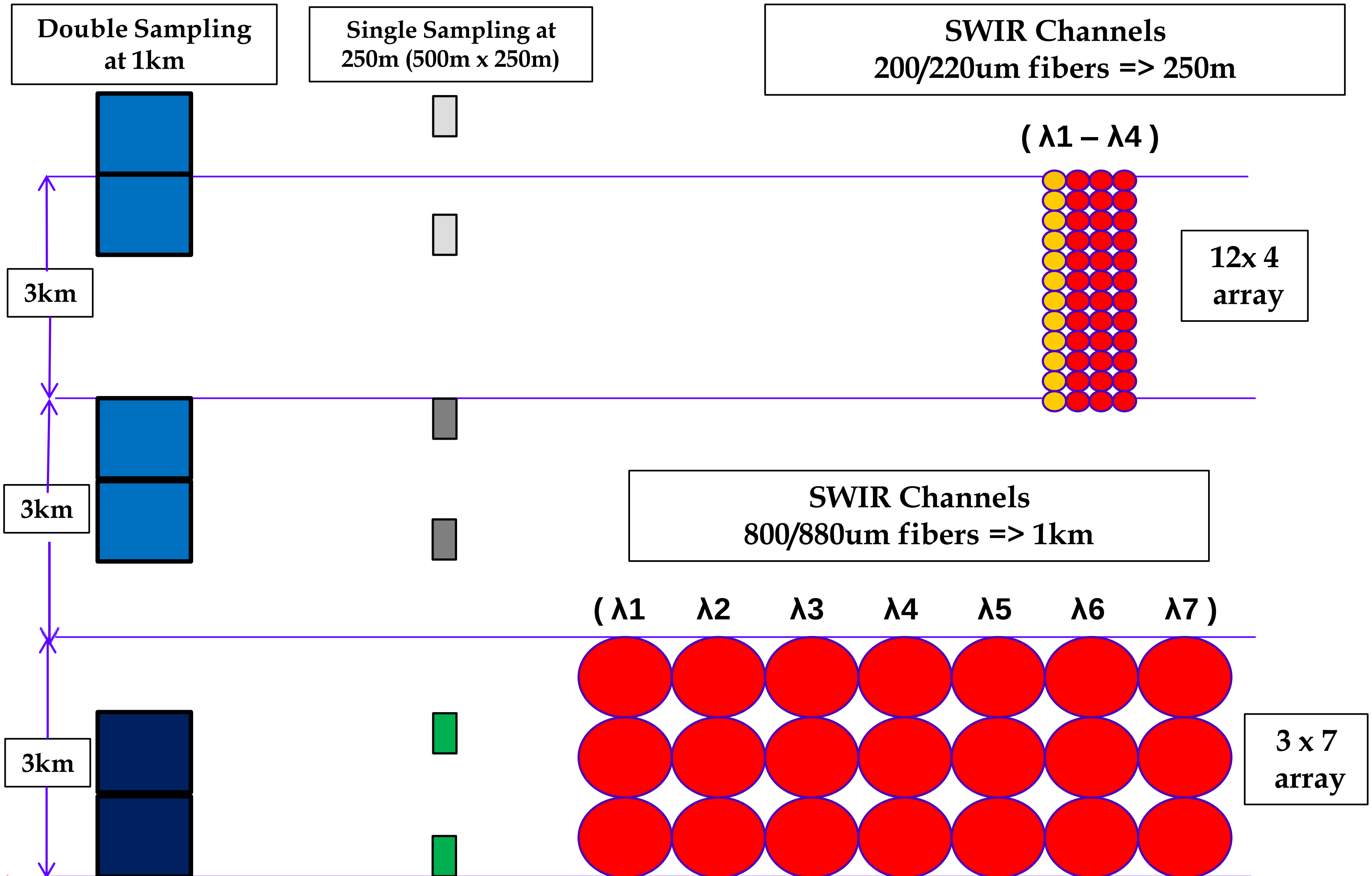
Ocean Color Experiment Ver. 3 (OCE3)

~ Concept Presentations~

Detectors

June 18, 2011

Focal Plane: Slits and Fiber Feeds



Detector Requirements

- **Highest Quantum efficiency: Very high signal to noise ratios (SNR) requirements mean the signal resulting from conversion of photons to electrons, needs to be as large as possible.**

- **Low Dark Current: Dark current contributes to the noise in the SNR in an RSS manner. Minimizing the dark current minimizes that contribution.**

- **Wavelengths of interest: Spectral coverage from 350nm to 830nm in 5nm increments at 1km spatial resolution. Spectral coverage from 350nm to 830nm in reasonable increments at 250m spatial resolution. Individual bands at 1225nm, 1640nm, 2135nm for Oceans and 763nm, 865nm, 940nm, 1378nm and 2250nm for atmospheric measurements.**

- **Two dimensional arrays are required for both the 1km spectrometers and the 250m spectrometers fed from the slits:**
  - One 1km ground pixel becomes a 400um square on the detector focal plane
    - Using 25um detector pixels, each ground pixel is 16X16 detector pixels
  - One 250m ground pixel becomes a 100um square on the detector focal plane
    - Using 25um detector pixels, each ground pixel is 4X4 detector pixels

  - Note: 25um pixel size is readily available both in hybridized PIN diodes arrays and CCDs

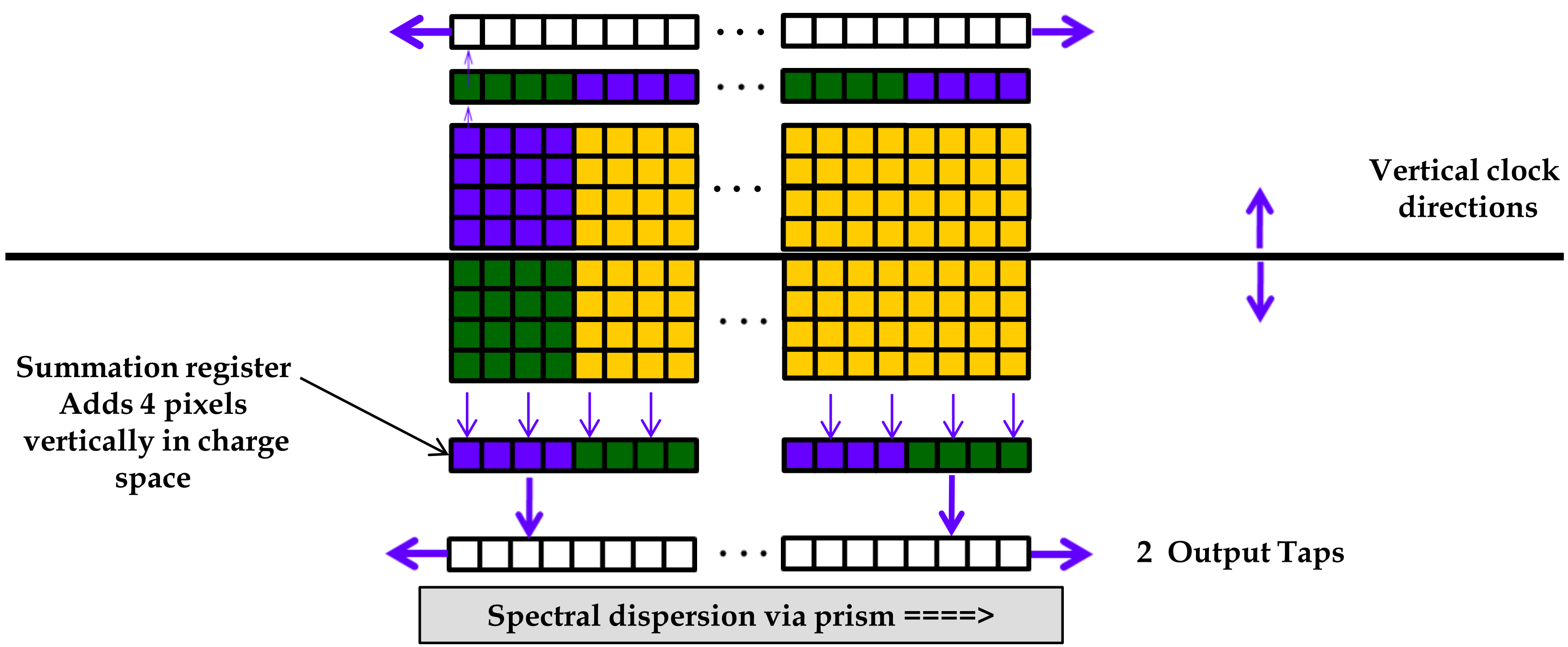
Detector Requirements Continued

- **An extremely high readout speed is dictated by the extremely short integration period, necessitating the use of custom arrays.**
  - Hybridized PIN diode arrays (ex. Indigo 9803, HAWAII-1RG) would require more output taps
    - Feasibility unknown as well as vendor willingness unknown
  - Standard CCDs have too many pixels and too few output taps
    - Several vendors are available to make custom CCDs

- **Individual fiber fed photodiodes optimized for each of the (8) individual band center wavelengths. Silicon is the detector of choice from 350 to 900nm. The 940nm detector could be either Silicon or InGaAs. The remainder of the IR bands require the use of InGaAs.**
- **For the 763nm, 865nm and 940nm bands, the Silicon photodiodes need a thicker than standard active area to improve the longer wavelength performance. This is already done routinely by the vendors.**
- **Standard composition InGaAs with 1.7um cutoff can be used for 940nm, 1254nm, 1378nm, and 1640nm bands. Strained layer, longer 2.4um cutoff material is required for the 2135nm and 2250, but is a standard product.**
- **The anti-reflection (AR) coatings for the Si detectors should be different (optimized) for the different sections of the spectrum of interest. The IR detectors are already coated for the narrow band for which they are efficient.**

Back-to-Back CCD Array layouts
One 250m ground pixel=>4x4 pixels

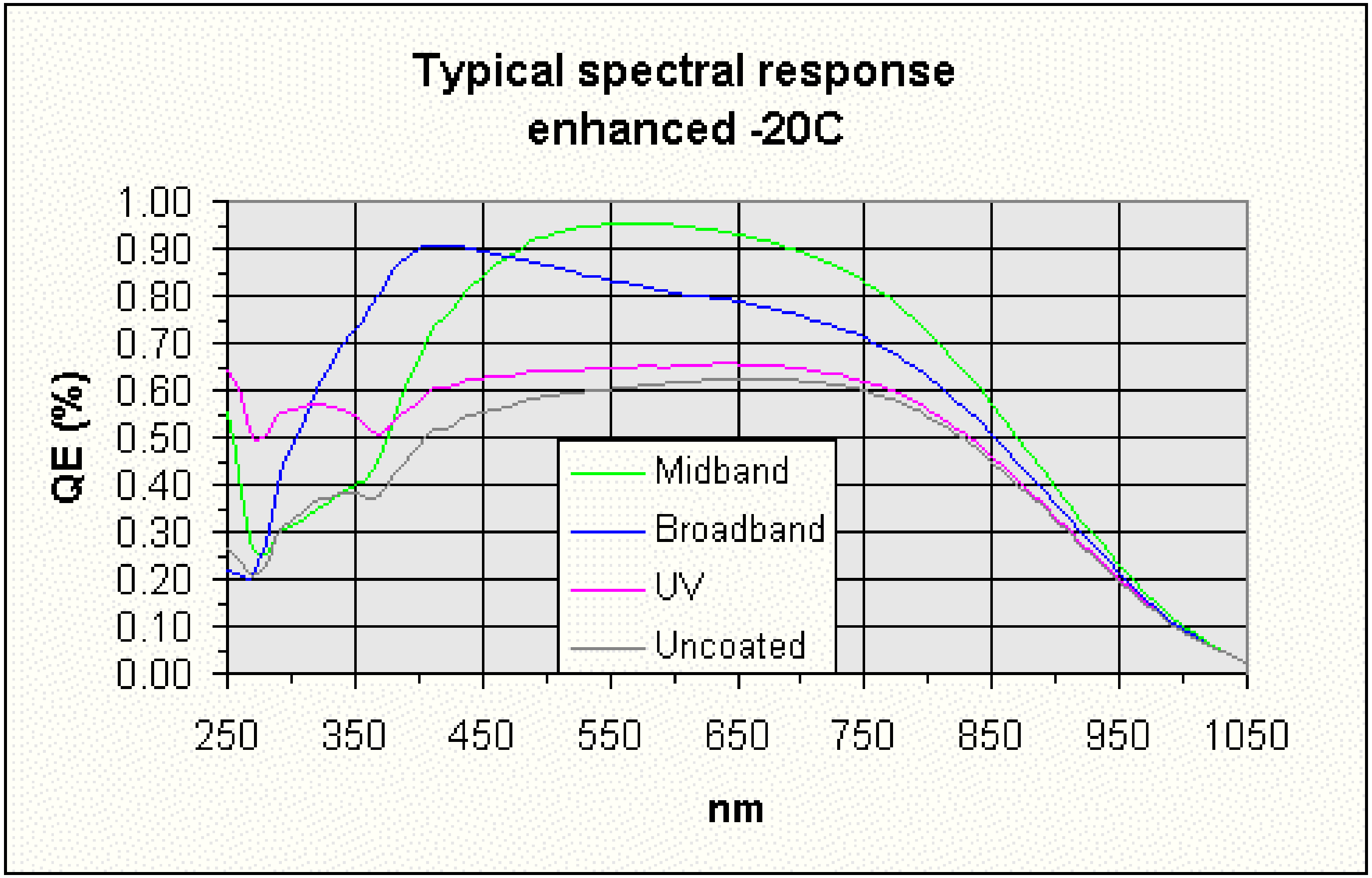
Each Detector Pixel = 25um x 25um
250m => 4 x 384 elements per array
(12) Arrays total on same Silicon chip



1km Arrays: Same principal, 16x16 pixels => one ground pixel

Each array 16 rows X 768 columns, (2) arrays back to back, (6) arrays total on the same Silicon Chip

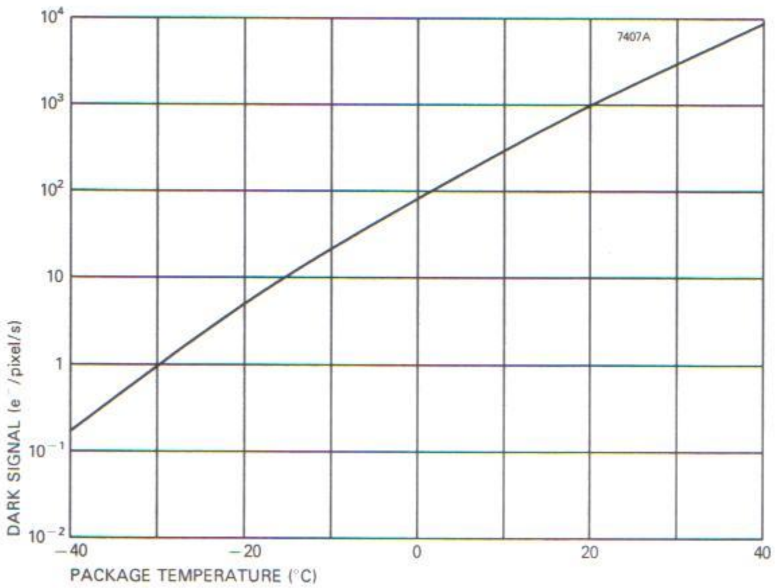
Typical E2V CCD QE Performance



Use a broadband AR coating for the Blue 1km CCD
Use Midband coated devices for the Red 1km CCD and the 250m CCD

CCD Operating Temperature

TYPICAL VARIATION OF DARK SIGNAL WITH TEMPERATURE



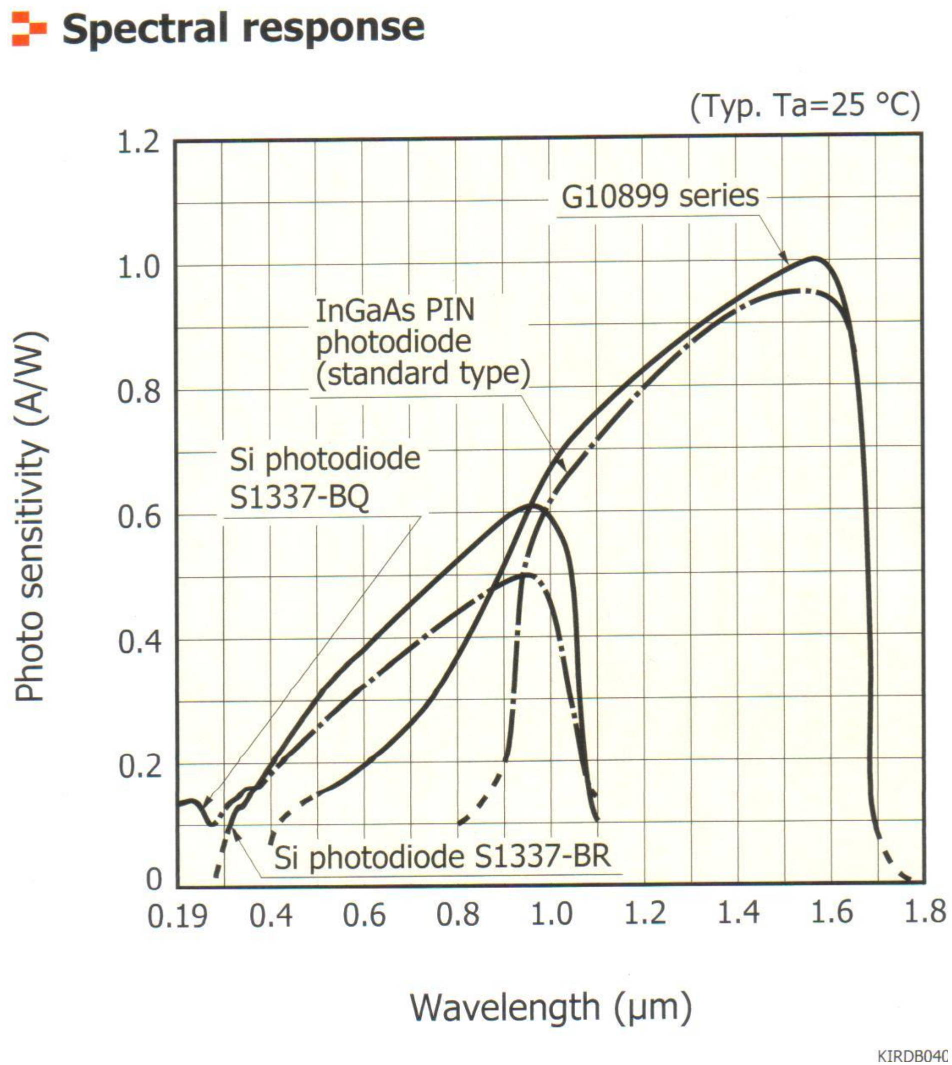
- SNR requirements dictate a dark current (signal) of <5000e-/pix/sec.
- Operating at 10C results in <500e-/pix/sec for a 26um pixel.
- Total radiation dose has been calculated to be 14.6krad with 2.5mm shielding, 5krad with 5mm shielding.
    - Baseline recommendation of 5mm
    - Increasing the thickness further does little to further reduce the dose
    - Using a 2x safety margin, a 10krad total dose should be used. Radiation effects such as CTE degradation and increased dark signal can start to be observed after 5krad.

The total dose effect on the Si-Oxide interface, which manifests itself in reduced CTE, is reduced by operating near RT since the generated charges maintain enough mobility to be swept out by the applied voltages, albeit slowly. CCDs that are operated at low temperatures are commonly warmed up to “anneal” this damage. However, the displacement damage in the lattice creates traps that cannot be annealed out. When CCDs are operated at low temperature, the traps get filled and remain filled. But when operated at room temperature, the electrons in the traps are released in a random manner contributing a spurious or noise signal. This effect is not large enough in this instance to be of concern to warrant a lower operating temperature such as -100 or -120C. Even if the dark current triples, it is tolerable given the requirement.

Photodiode Spectral Response

- **Comparison of typical Hamamatsu Si and InGaAs photodiodes shows the crossover point at ~950nm so either type could be used at the 940nm band.**
  - Si does not require a reduced operating temperature

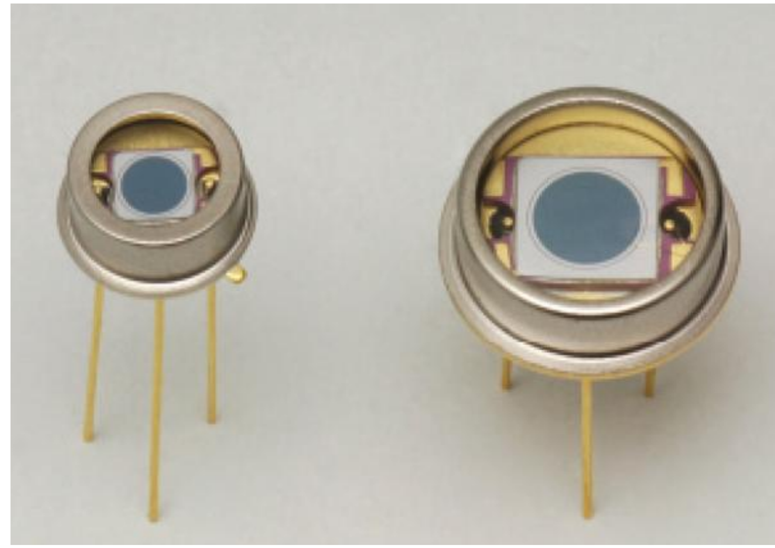
- **To convert responsivity in A/W to quantum efficiency (electrons/photon), one must convert amps to electrons per second and convert watts to photons per second, which is wavelength dependent.**



Silicon Detector Examples

Integrated Design Capability / Instrument Design Laboratory

- Silicon photodiodes are available in standard TO-5 cans (smaller 9mm diameter). They can be bought without the window. Some venders can supply a preamp in the package with the detector, but these are noisier than what can be tolerated in this application. Unpackaged detector chips could also be procured and mounted directly to the ceramic circuit board to minimize capacitance. Specs below are for typical 3mm and 5mm diameter Silicon PIN photodiodes from Hamamatsu.



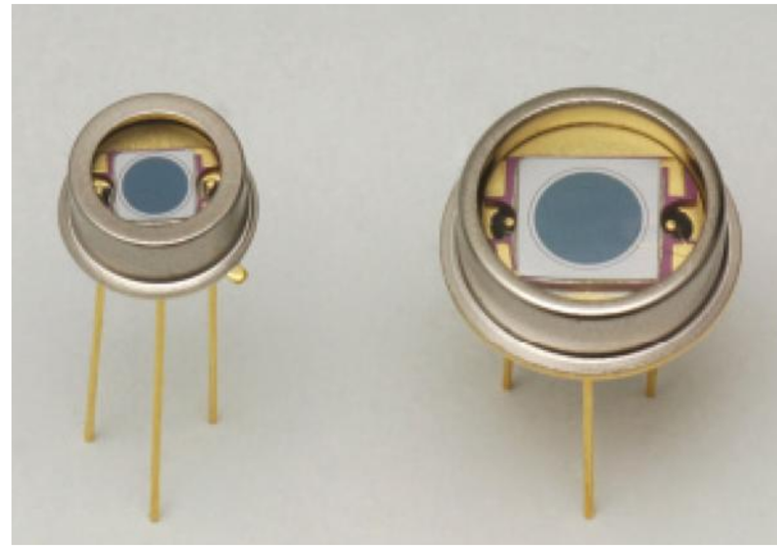
Electrical and optical characteristics (Typ. Ta=25 °C, unless otherwise noted)

Type No.	Spectral response range λ (nm)	Peak sensitivity wavelength λp (nm)	Photo sensitivity S (A/W) λp	Photo sensitivity S (A/W) GaP LED 560 nm	Photo sensitivity S (A/W) He-Ne laser 633 nm	Photo sensitivity S (A/W) GaAs LED 930 nm	Short circuit current Isc 100 lx Min. (µA)	Short circuit current Isc 100 lx Typ. (µA)	Dark current ID VR=10 mV Max. (pA)	Temp. coefficient of ID TCID (times/°C)	Rise time tr VR=0 V RL=1 kΩ (µs)	Terminal capacitance Ct VR=0 V f=10 kHz (pF)	Shunt resistance Rsh VR=10 mV Min. (GΩ)	Shunt resistance Rsh VR=10 mV Typ. (GΩ)	NEP VR=0 V λ=λp (W/Hz$^{1/2}$)
S2386-18K	320 to 1100	960	0.6	0.38	0.43	0.59	1	1.3	2	1.12	0.4	140	5	100	6.8×10^{-16}
S2386-18L							4	5.7							
S2386-5K							4.4	6.0	5		1.8	730	2	50	9.6×10^{-16}
S2386-44K							9.6	12	20		3.6	1600	0.5	25	1.4×10^{-15}
S2386-45K							12	17	30		5.5	2300	0.3		
S2386-8K							26	33	50		10	4300	0.2	10	2.1×10^{-15}

* Window material K: borosilicate glass, L: lens type borosilicate glass

Example InGaAs Detectors

- InGaAs photodiodes are also available in standard TO-5 cans. Can be purchased without the window. Some venders can supply a preamp in the package with the detector but these are noisier than what can be tolerated in this application. Unpackaged detector chips could also be procured and mounted directly to the ceramic circuit board to minimize capacitance. Specs below for typical 0.3mm to 3.0mm diameter InGaAs PIN photodiodes from Hamamatsu.



Electrical and optical characteristics (Ta=25 °C)

Type no.	Spectral response range λ (μm)	Peak sensitivity wavelength λp (μm)	Photo sensitivity S, λ=0.65 μm, Min. (A/W)	Photo sensitivity S, λ=0.65 μm, Typ. (A/W)	Photo sensitivity S, λ=0.85 μm, Min. (A/W)	Photo sensitivity S, λ=0.85 μm, Typ. (A/W)	Photo sensitivity S, λ=1.3 μm, Min. (A/W)	Photo sensitivity S, λ=1.3 μm, Typ. (A/W)	Photo sensitivity S, λ=λp, Min. (A/W)	Photo sensitivity S, λ=λp, Typ. (A/W)	Dark current ID VR=1 V, Typ. (nA)	Dark current ID VR=1 V, Max. (nA)	Cut-off frequency fc VR=1 V RL=50 Ω (MHz)	Terminal capacitance Ct VR=1 V f=1 MHz (pF)	Shunt resistance Rsh VR=10 mV (MΩ)	D* λ=λp (cm · Hz$^{1/2}$/W)	NEP λ=λp (W/Hz$^{1/2}$)
G10899-003K											0.3	1.5	300	10	1000		5×10^{-15}
G10899-005K											0.5	2.5	150	20	300		9×10^{-15}
G10899-01K	0.5 to 1.7	1.55	0.15	0.22	0.35	0.45	0.8	0.9	0.85	1	1	5	45	70	100	5×10^{12}	2×10^{-14}
G10899-02K											5	25	10	300	25		4×10^{-14}
G10899-03K											15	75	5	600	10		6×10^{-14}

Detector packaging

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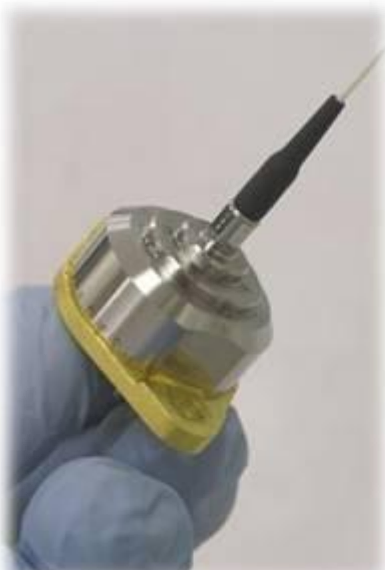
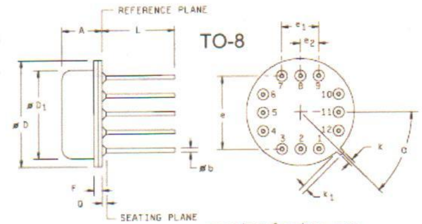


Transistor Can Packages TO-8 Case style, Metal Can

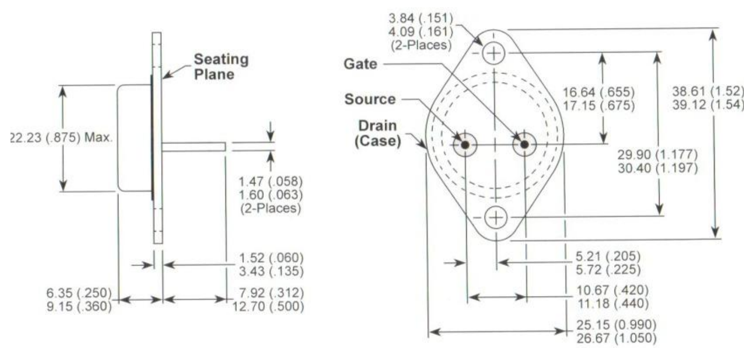


www.interfacebus.com

Symbol	Millimeter		Inches	
	Min	Max	Min	Max
A	4.57	5.08	.180	.200
Øb	0.41	0.51	.016	.020
ØD	14.99	15.49	.590	.610
ØD1	13.97 REF		.550 REF	
e	10.16 REF		.400 REF	
e1	5.08 REF		.200 REF	
e2	2.54 REF		.100 REF	
F	0.56	0.76	.022	.030
k	0.66	0.91	.026	.036
k1	0.66	0.91	.026	.036
L	6.10	-----	.240	-----
Q	-----	1.14	-----	.045
α	45° BSC		45° BSC	

12-Lead TO-8 Metal Can

TO-3 (TO-204AE) Package Outline

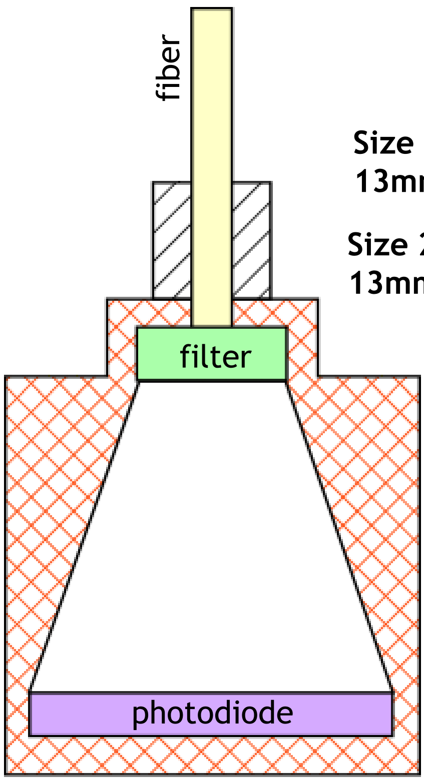


Dimensions in Millimeters and (Inches)

- **Photos courtesy of AVO: jdallas@avophotonics.com**

Fiber Terminator Options

As described by industry (2 vendors)

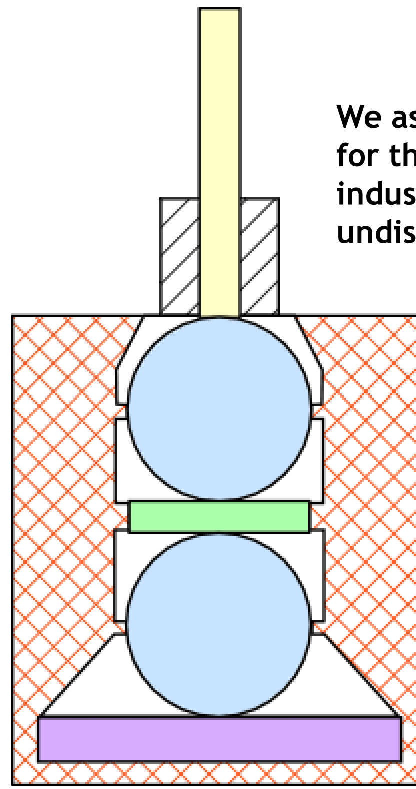


Size 1 (250m): 14mm diam, 13mm height

Size 2 (1km): 22mm diam, 13mm height

We suspect this is the function inside the connector terminator, as the vendor did not disclose it - it is not ideal because incident light on the filter is coming in at off normal angles

The hardware we've realized in our mass model, because we're certain it can work

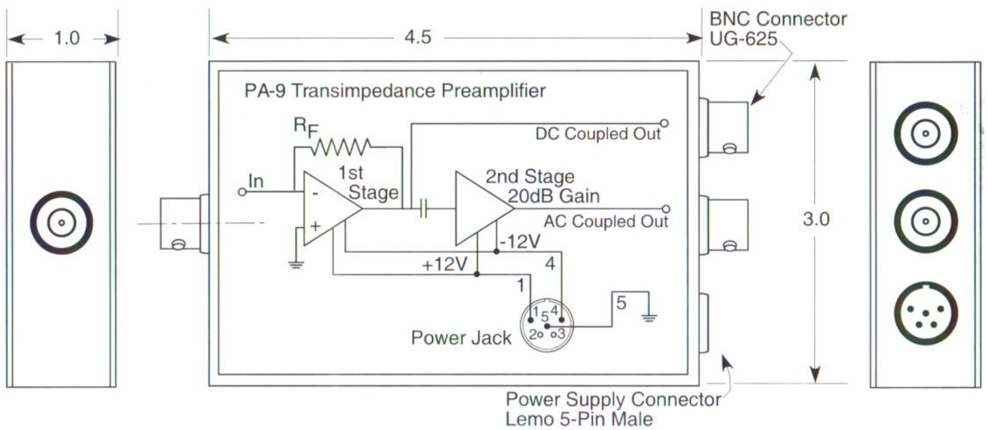


We assumed the same sizes for this approach as industry proposed for their undisclosed design

The ball spheres mimic the same function as we have shown in the larger singlet design, but keeps all incident light on the filter closer to normal for less loss in thru-put

Commercial Preamplifiers

Figure 51-1
PA-9 Preamplifier



Typical Specifications **Model PA-9** Preamplifiers

2nd Stage Gain	20	dB
Voltage Noise Density @1KHz	6.5	nV $Hz^{-1/2}$
Voltage Noise from 0.1 to 10 Hz	1.0	µVpp
Current Noise Density @ 1KHz, 10^7 Gain †	0.04	pA $Hz^{-1/2}$
Input Offset Voltage	± 10	mV
Input Bias Current	± 1	pA
Maximum Output	1st stage = 6 2nd stage = 10	Vpp
Output Impedance	< 50	
Power Requirements	+12 and -12 20	VDC mA

† Lower gain increases Current Noise Density

Judson, now part of Teledyne, PA-9 preamp

Conclusions

- **No technical issues or concerns**
  - Custom CCDs readily available
    - Can be optimized for the wavelength ranges of interest
  - Both individual photodiode detector types are readily available from multiple vendors
    - Silicon: Hamamatsu, Pacific Semiconductors, Perkin Elmer, Code 553, etc., etc.
    - InGaAs: Hamamatsu, Sensors Unlimited, Discovery Semiconductors
  - Fiber optic termination packages containing a filter, lens and photodiodes readily available.
  - No new technology developments required